

IDENTIFYING DISRUPTIVE TECHNOLOGIES FACING THE
UNITED STATES IN THE NEXT 20 YEARS

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Strategy

by

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

IDENTIFYING DISRUPTIVE TECHNOLOGIES FACING THE UNITED STATES IN THE NEXT 20 YEARS by MAJ Samuel T. Mitchell II, 92 pages.

The term “disruptive technology” is used to in the 2004 US National Defense Strategy and 2006 US National Security Strategy as a concern of the US Government. A study of potential disruptive technologies that will affect the way war in the future is fought is essential to prepare the US Army and the United States in general so that it will not lose its next war. This thesis will analyze commercial disruptive technology, determine how the United States is pursuing disruptive technology, determine what the stages of military disruptive technology are, and the differences in pursuing and evaluating military disruptive technology versus commercial disruptive technology, and what the United States is doing to prevent technological surprise in the next 20 years.

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ACRONYMS

AI	Artificial Intelligence
C2	Command and Control
CDIATFR	Committee on Defense Intelligence Agency Technology Forecasts and Review
CFFDT	Committee on Forecasting Future Disruptive Technologies
DARPA	Defense Advanced Research Projects Agency
DR&E	Defense Research and Engineering
DDR&E	Director, Defense Research and Engineering
DIA	Defense Intelligence Agency
DIATWD	Defense Intelligence Agency Technology Warning Division
DWO	Defense Warning Office
EMP	Electromagnetic Pulse
IFTF	Institute for the Future
NAE	National Academy of Engineering
NAS	National Academy of Sciences
NDS	National Defense Strategy
NGIC	National Ground Intelligence Command
NMSS	National Military Security Strategy
NRC	National Research Council

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CHAPTER 1

WHAT IS MILITARY DISRUPTIVE TECHNOLOGY?

. . . now I am become Death [Shiva], the destroyer of worlds . . .

— Robert Oppenheimer,
White Sands Missile Range, July 16, 1945.

Perhaps the most devastating example of disruptive technology in recent history is the atomic bomb. A few days after the first test, a second test confirmed that the first bomb was not a fluke. On August 6, 1945, the third atomic bomb leveled Hiroshima, Japan, incinerating 70,000 people.¹ Three days later, 20,000 more people died in Nagasaki, Japan² to the fourth atomic bomb. Before August 6, 1945, the world, with the exception of few who knew the full scope of the program working in the United States, was oblivious to the weapon conceived and developed over the previous six years. The development of the bomb and its implementation changed the laws of war and gave a new extreme to the concept of total war previously held by the fire-bombings on mainland Germany during World War II. The undeniable fact of this episode in disruptive technology is that Japan's capitulation brought the Second World War to a strategic close less than five days after the second bomb.

What is Disruptive Technology?

“Disruptive technology” is a term coined in 1995 by Joseph L. Bower and Clayton M. Christensen to describe the phenomena of entrenched commercial technology being replaced by new technology. The term describes how new technologies or innovations made entrenched technologies or innovations obsolete in only a few years.³

In order for a new disruptive technology to be viable for an entrenched business, the disruptive technology must become ~~–sustaining.~~”⁴ In the marketplace, typically only a new start-up company will develop new potential disruptive technology because they lack a customer base and cater to the ~~–fringe~~” market.⁵ However, what makes the technology disruptive is that before the entrenched company realizes the change in the marketplace, the new technology has invaded the established market and made the entrenched technology obsolete.

The term ~~–military innovation~~” was arguably the closest in defining military areas of disruptive technology. However, the military thinkers addressing the issue of military innovation probably did not realize that in many cases, they were discussing disruptive technologies. Stephen P. Rosen, in *Innovation and the Modern Military: Winning the Next War*, studies military innovation from the early 1900s to the mid 1950s. He divides military innovations into three areas; peacetime, wartime, and technological.⁶ He also proposes problems with each of these innovation frameworks. Within peacetime innovation, he says that defeat in war is neither required nor sufficient to produce innovation.⁷ He states that innovation is hardly driven from internal military leadership but rather from civilian intervention within the military structure during peacetime.⁸

The 2004 National Military Security Strategy of the United States of America called worldwide technology diffusion a catalyst enabling adversaries to gain disruptive technology which could marginalize United States technological superiority.⁹ Access to advanced weapons and delivery systems by state or non-state foreign actors requires the United States military to continue to transform in order to meet these new challenges.¹⁰ While the National Military Security Strategy used the term ~~–disruptive technology~~ and

weapons” and named ~~—~~“dual-use civilian technologies, especially information technology, high resolution imagery, and global positioning systems”¹¹ as pieces of technology that will empower state and non-state actors with new disruptive and destructive capability¹², it failed to further define what exactly disruptive technology is. It gave one certain criterion which was that these technologies could ~~—~~“dramatically increase an adversary’s ability to threaten the United States.”¹³

~~—~~“Disruptive challenges” was named in the 2006 National Security Strategy of the United States as one of the things which spurs a need for the Department of Defense to transform itself to better balance its capabilities.¹⁴ It named biotechnology, cyber and space operations, and directed-energy weapons as chief concerns in its definition of disruptive challenges.¹⁵ It warns that state and non-state actors may employ weapons or techniques in ways that would counter the United States’ military advantage.¹⁶ The National Security Strategy defined a disruptive challenge, but did not define disruptive technology. However, when compared to similar language within the 2004 National Military Strategy, they both seemed to define the same thing. The question becomes, what exactly is disruptive technology in the military context? Is it the same as disruptive technology in the business world?

Neither of the two documents provided insight into how the United States is identifying disruptive technology, but to use a cliché, they ~~—~~“know it when they see it.” Terry J. Pudas defines a ~~—~~“disruptive challenge” as a ~~—~~“challenge from adversaries who seek to develop and use breakthrough capabilities to negate current U.S. military advantages in key operational domains.”¹⁷ Again this is a strong definition which defined

operational advantage in reference to disruptive challenge. This definition of disruptive challenge was similar to Bower and Christensen's definition of disruptive technology.

The area of disruptive technology was important enough in 2004 for the Defense Intelligence Agency to task the National Research Council to create the Committee on Defense Intelligence Agency Technology Forecasts and Reviews with the specific statement of task:

Establish an ad hoc committee to provide technology analyses, both near and far term, to assist the agency to develop timelines, methodologies, and strategies for application of identified technologies of interest to the Defense Intelligence Agency (DIA) under development within the United States and its allies and to bring to the agency's attention potentially useful technologies that DIA may not be aware of that might be of value for adaptation and consideration.¹⁸

The first and second of four report statement of tasks are:

Develop, examine and review from unclassified sources evolving technologies that will be critical to successful U.S. warfighting capabilities. Postulate methods for potential adversaries of the United States to disrupt these technologies and discuss indicators for the intelligence community to investigate to determine if RED force elements are attempting to achieve this disruptive capability. . . .¹⁹

Clearly, the Defense Intelligence Agency has a similar understanding of what disruptive technology is when litmus-ed against Pudas' "disruptive challenge" and the 2006 National Security Strategy's "disruptive challenge."

However, the question remains of whether a military disruptive technology follows relatively the same definition of a commercial disruptive technology. In the case of a commercial disruptive technology theory, the disruptive technology replaces the entrenched technology by appealing to a "fringe" customer base and then becomes the standard before the entrenched company realizes its replacement. In the case of

–disruptive challenge”, adversaries intend to develop or acquire disruptive technology that will negate the United States military’s technological advantage.

Therefore, disruptive technology when used in reference to military use, must be modified to —military disruptive technology” because of the differences based on the strategic, operational and tactical impact that the disruptive technology will have when employed against the United States. As the Committee on Defense Intelligence Agency Technology Forecasts and Reviews infers, there must be a way to evaluate new disruptive technologies that can be converted to military disruptive technologies when applied in tactical situations. This identification is of strategic importance to the security of the United States, but this is only half of the problem. The second half of the problem is what the United States is doing to negate or reduce –technological surprise” on the battlefield.

Primary Research Question

How is a military disruptive technology identified?

Secondary Research Questions

Secondary Question 1: What is military disruptive technology?

Secondary Question 2: What are the differences in evaluating commercial disruptive technology and military disruptive technology?

Secondary Question 3: What are the stages of a military disruptive technology?

Secondary Question 4: What is the United States doing to prevent technological surprise by an adversary using potential disruptive technology on the battlefield?

Definitions

A complete glossary of terms used throughout this thesis is located in the glossary. However, there are several terms used throughout this paper that require a basic understanding and context in this thesis. They are listed below:

Disruption Technology: A technology that causes disarray or increases fog of war for an adversary.

Disruptive Challenge: Challenges from adversaries who seek to develop and use breakthrough capabilities to negate current U.S. military advantages in key operational domains.

Disruptive Technology: A technology that improves a product or service in ways that the market does not expect.

Military Disruptive Technology: A military technology that provides strategic, operational, or tactical advantage over an adversary.

Sustaining Technology: Technology that maintains a steady rate of improvement.

Technological Surprise: Technology that is introduced which has not been foreseen or prepared for by an adversary.

Significance

This thesis addresses and defines what a military disruptive technology is for the next 20 years. Almost all literature prior to 2000 was written from an economic and market-based introduction of disruptive technology. Prior to 1995, the term “military innovation” was generally used to define aspects of what is now known as disruptive technology in reference to military application. The identification of new military disruptive technologies by the United States prior to their implementation by an

adversary on the battlefield is essential to prevent technological surprise which could cause a strategic defeat. The understanding of what the basic stages of military disruptive technology is also important because, once a military disruptive technology has been identified, it is essential to prevent technological surprise on the battlefield. The United States has a stake in either developing military disruptive technologies or defenses against them if it wishes to remain a superpower past the next 20 years.

Assumptions

This thesis is limited in scope and assumes that quantifiable or qualitative criteria can, in fact, be determined to evaluate military disruptive technology. This thesis also assumes that nations, individuals, and groups are not confined to accepted moral law in the development of military disruptive technology. This thesis also assumes that technology, science, and invention will not remain stagnant for the next 20 years.

Limitations

Disruptive technology literature is only about fourteen years old. The context in it was developed is a market theories-based approach to demonstrate how new technologies or innovations can sustainably take over the market place in a short period of time.

Because of this, almost all literature addressing disruptive technology is from a market enterprise standpoint. The term —disruptive technology” is specifically used in the 2004 National Security Strategy and the 2006 National Military Strategy and therefore, means that there is reference to disruptive technology beyond the market-based theory.

Disruptive technology has become synonymous with technological revolution with regards to military doctrine and combat. This thesis will deal with military disruptive

technology from a United States military and security standpoint. It is quite easy to look at industry journals and magazines with incredible amounts of information on singular topics and lose perspective on other technologies. This thesis only looks at two common magazines, *Popular Science* and *Popular Mechanics* to determine trends in new technology development during the last eight years.

Delimitations

This thesis will not address any moral debates other than to point out the moral question that a new disruptive technology may pose in military application. The intent of this thesis is limit research into disruptive technologies from 1999 forward. The research will be conducted with respect to potential military application of disruptive technologies that may enhance or change the way war is fought with emphasis on disruptive technology that may cause technological surprise when implemented on the battlefield. This thesis will dwell in open-source information derived from reports, essays, articles, and online information.

Chapter Summary

In summary, this thesis intends to identify what the characteristics of a military disruptive technology are for the next 20 years. The purpose of this thesis is to determine if disruptive technology is known by different names and whether or not those names or ideas are actually disruptive technology or not. The research conducted for this thesis will determine if the United States military is looking at the right categories of disruptive technology. Additionally, this thesis will examine a few potential disruptive technologies that the United States might see in the next 20 years. This thesis will also discuss the

importance of predicting and developing new disruptive technologies from the military standpoint to prevent technological surprise. Finally, this thesis will discuss measures of effectiveness for evaluating new disruptive technologies.

¹Harry S. Truman Library and Museum Website, “Atomic Bomb-Truman Press Release-August 6, 1945,” trumanlibrary.org, www.trumanlibrary.org/teacher/abomb.htm (accessed September 8, 2009).

²Ibid.

³Joseph L. Bower and Clayton M. Christensen, “Disruptive Technologies: Catching the Wave,” *Harvard Business Review* (January-February 1995): 1.

⁴Ibid., 2.

⁵Peter Dombrowski and Eugene Gholz, “Identifying Disruptive Innovation: Innovation Theory and the Defense Industry,” *Innovations* 4, no. 2 (Spring 2009): 101.

⁶Stephen Peter Rosen, *Innovation and the Modern Military: Winning the Next War* (Ithaca, NY: Cornell University Press, 1991) 6.

⁷Ibid., 9.

⁸Ibid.

⁹United States Government, *The National Military Strategy of the United States of America: A Strategy for Today; A Vision for Tomorrow* (Washington, DC: Government Printing Office, 2004), 6.

¹⁰Ibid.

¹¹Ibid.

¹²Ibid.

¹³Ibid.

¹⁴United States Government, *The National Security Strategy of the United States of America* (Washington, DC: Government Printing Office, March 2006), 44.

¹⁵Ibid.

¹⁶Ibid.

¹⁷Terry J. Pudas, —Disruptive Challenges and Accelerating Force Transformation,” *Joint Forces Quarterly*, no. 42 (3d Quarter 2006): 44.

¹⁸National Research Council, *Avoiding Surprise in an Era of Global Technology Advance* (Washington, DC: The National Academic Press, 2005), 2.

¹⁹*Ibid.*

CHAPTER 2

LITERATURE REVIEW

The literature review for this thesis is organized into four sections with some subsections within each. Section one includes further definitions of disruptive technology and innovation. Section two provides information on how military disruptive technology is currently being evaluated. Section three will discuss randomness and inventions which addresses technological surprise. Finally, section four will show why, how and who develops commercial disruptive and military disruptive technology.

The term “~~is~~ruptive technology” was coined in 1995 to describe new technologies or innovations that make entrenched technologies or innovations obsolete in only a few years. Internet research on the subject with “~~is~~ruptive,” “~~is~~nnovative,” “~~is~~volutionary,” and “~~is~~volutionary” with “~~is~~technology” and “~~is~~nnovation” reveals several thesis, articles, and web-published articles on the subject. Christensen and Bower also propose that in order for the new disruptive technology to be viable it must transform into a “~~is~~sustaining technology.” Sustaining technology is duplicable and cheaper than its initial prototype in the commercial environment. However, this term was developed in reference to economics and the markets.

This term was created by Clayton M. Christensen and Joseph Bower in their article, “~~is~~ruptive Technologies: Catching the Wave” in *Harvard Business Review*, January-February 1995. They are able to show several technologies and innovations in their article that completely replaced entrenched technologies and business methods. Christensen has authored and co-authored (as he and Bower coined the phrase) several

works that address disruptive technology in the business and sociology and in order to help develop evaluation criteria for the identification of disruptive technology.

A simple graph displays how disruptive technology and sustaining technologies emerge. In this graph, the entrenched manufacturer continues to refine the current technology which is sustaining. It is refined because the manufacturer's customers require high end performance. Disruptive technology does not generally start as high end performance and, therefore, only requires low end performance. However, as the new disruptive technology becomes entrenched and improved, it will eventually replace the previously sustained technology.

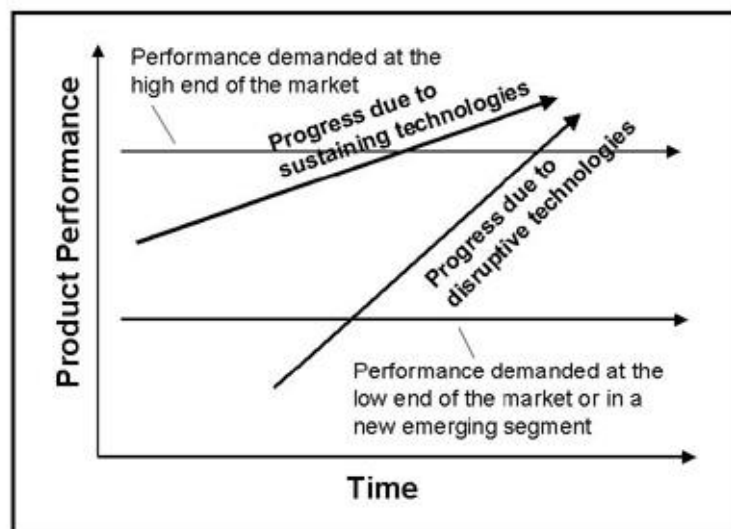


Figure 1. Disruptive versus Sustaining Technologies

Source: <http://web.mit.edu/6.933/www/Fall2000/teradyne/clay.html>

Further Clarification of Disruptive Technology

Before “disruptive technology,” the term “military innovation” was probably the closest in defining areas of disruptive technology. However, the military thinkers addressing the issue of military innovation probably did not realize that in many cases, they were discussing military-based disruptive technologies. In *Innovation and the Modern Military: Winning the Next War*, Rosen studies innovation from the early 1900s to the mid 1950s. He divides innovations into three areas; peacetime, wartime, and technological.¹ He also proposes problems with each of these innovation frameworks. Within peacetime innovation, he says that defeat in war is neither required nor sufficient to produce innovation.² He states that innovation is rarely driven from internal military leadership and is usually derived from civilian intervention within the military structure during peacetime.³

Rosen identified a difference between militaries of World War I and World War II and the last quarter of the 20th Century in that leadership frequently led their troops in battle and there was a large turnover in leadership due to casualties on the battlefield. Thus, military innovation within wartime is generally conducted by military leadership with great risk.⁴ This risk becomes more pronounced if the new military chain of command was not present at previous failures to learn from those failures and thus apply those lessons.⁵ Rosen believes that organizational learning must take place in order to learn from previous mistakes to develop better and new innovations to conduct wartime operations.⁶ The difference apparent today between the militaries of the World War II and today is that there is more military innovation undertaken by military leaders in order to maintain the technological edge over adversaries.

Technological innovation deals with building machines.⁷ Rosen points out that the problem with technological innovation is that the weapons development process generally does not take place in military circles.⁸ Rather innovation is driven from the research labs, industry and universities.⁹ Before the late 20th Century, the ideas of new technological innovations did not come from the military sector, they were pushed and adapted from the civilian technology developers. From the late 20th Century into the early 21st Century, the military seems to have changed and requested more from the civilian technology development sector to enable it to maintain its technological edge. Rosen's definition of technological innovation could be considered the precursor of disruptive technology from the military standpoint.

John C. Keefe in his article, "Disruptive Technologies for Weapon Systems: Achieving the Asymmetric Edge on the Battlefield" continues to provide definitions for what disruptive technology is with respect to military applications.¹⁰ He defines disruptive technology as "an innovation that forces the advancement in security or degrades current security as related to changes in geopolitical, military, economic or social factors."¹¹ Keefe says that it is of extreme importance that the newest emerging technologies must be advanced as soon as possible¹² because it will reward those who get it to the field quickly.¹³ He goes on to say that specific technologies must be identified early to continue the United States asymmetrical advantage.¹⁴

Keefe gives four areas to spur the development of new disruptive technologies:

1. Awarded grants that are intended to develop new technologies and methodologies.
2. New programs that are starting up to discover what is being developed.

3. New product offerings in the commercial market.
4. Combinations of conventional technologies that synergize and result in new disruptive technology.¹⁵

Keefe also names biotechnology, nanotechnology, and information technology as areas of disruptive technology.¹⁶ Additionally, Keefe acknowledges many technologies that in themselves could spawn disruptive technologies themselves or when combined could create disruptive technologies.

Terry Pudas, in his *Joint Forces Quarterly* article, “Disruptive Challenges and Accelerating Force Transformation,” lists four security challenges as traditional, irregular, catastrophic, and disruptive in nature.¹⁷ As military leaders prepare for the next conflict, they are entrenched in the tactics of the previous war and do not plan for potential disruptive challenges.¹⁸ Pudas asserts that military planners spend a majority of their time working on unanticipated events that may be faced on the battlefield not necessarily worrying about unanticipated disruptive challenges that could cause our forces to be “swept off the battlefield.”¹⁹ Military thinkers and strategists are more apt to deal with traditional, irregular, and catastrophic challenges vice disruptive challenges and therefore spend more time developing contingencies and molding the army to win in light of these challenges (figure 3).

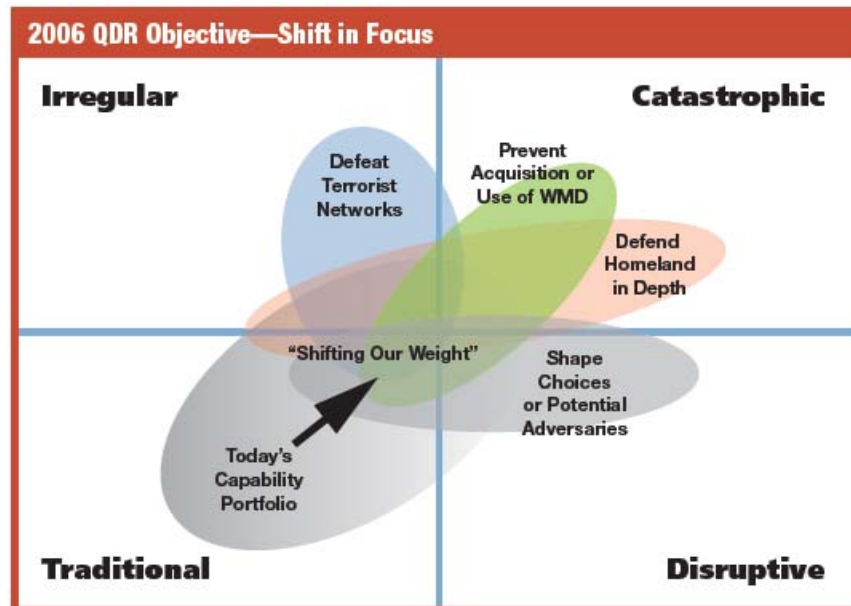


Figure 2. Department of Defense Shift in Focus to Address Four Security Challenges
 Source: Terry J. Pudas, “2006 QDR Objective-Shift in Focus,” *Joint Forces Quarterly* no. 42 (3d Quarter 2006): 45.

Pudas says the way the military counters disruptive challenges is three-fold. First, it attempts to narrow the range of disruptive challenges that will be faced by improved intelligence. Second, it formulates a force which is my flexible in its ability to deal with disruptive challenges. Finally, it attempts to dissuade attempts at disruptive challenges by accelerating force transformation (figure 4).²⁰ This unique approach uses intelligence, current asymmetric superiority, and counter-intelligence in order to keep the disruptive technology edge.

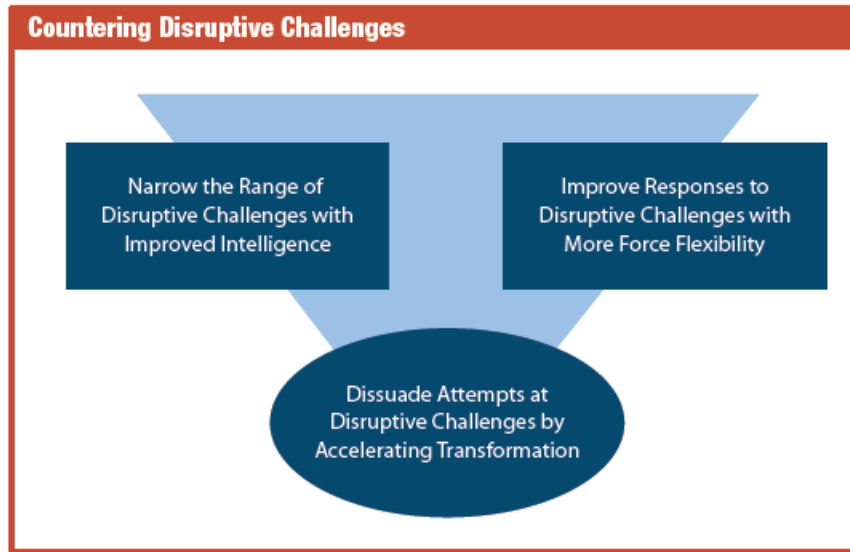


Figure 3. Countering Disruptive Challenges

Source: Terry J. Pudas, "Countering Disruptive Challenges," *Joint Forces Quarterly* no. 42 (3d Quarter 2006): 46.

How is Disruptive Technology Identified and Evaluated?

In *Identifying Disruptive Innovation: Innovation Theory and the Defense Industry*, Peter Dombrowski and Eugene Gholz examine disruptive technology and its transformation into a sustaining technology and propose that military procurement does not necessarily fall into the accepted commercial parameters of disruptive and sustaining technology conventional wisdom.²¹ They argue that military procurement does not have a "profit" motive but, rather fall into the "fringe" customer realm in disruptive innovation theory. Despite their assertion that the government does not have a "profit" motive, they point out that because the initial cost of disruptive technology development may be expensive, Congress still controls the purse strings and will not necessarily want to invest in warfare-changing disruptive technologies because of expense.

The Committee on Defense Intelligence Agency
Technology Forecasts and Reviews

The amount of disruptive technology being developed caused the Defense Intelligence Agency to request the National Research Council to establish the Committee on Defense Intelligence Agency Technology Forecasts and Reviews in 2004 to study potentials that might arise in the future. This committee's first requirement was to establish a long-term collaborative relationship between intelligence agencies to support the examination of technology warning issues. The committee also identified that the United States maintains its superiority through its technological superiority, but must continue to find, assess, and act upon these emergences. The committee developed a disruptive technology assessment chart for disruptive technologies that are being developed now and potentially will surface in the next 20 years (figure 4).

Technology		Observables
Brief description of technology		Brief description of observables.
Accessibility	Maturity	Consequence
Level 1, 2, or 3	Technology Futures Technology Watch Technology Warning Technology Alert	Short characterization.

Figure 4. Example of Technology Assessment Chart

Source: National Research Council, Example of Technology Assessment Chart, 25.

The definitions of each of the blocks are straightforward. The technology block gives a brief description of the technology and what sector it is in. Observables is a description of the actions that have been seen either covertly or open source on work being done on the assessed technology. Accessibility focuses on the question, *How*

difficult would it be for an adversary to exploit the technology? ”²² and evaluates each technology into three levels:

1. Level 1. The technology is available through the internet, being a commercial off-the-shelf item; low sophistication is required to exploit it.
2. Level 2. The technology would require a small investment (hundreds of dollars to a few hundred thousand dollars) in facilities and/or expertise.
3. Level 3. The technology would require a major investment (millions to billions of dollars) in facilities and/or expertise.²³

Maturity focuses on the question, *How much is known about an adversary’s intention to exploit the technology?* ”²⁴ and divides the answer into four categories which indicate actions that need to be taken concerning this disruptive technology. These four levels are:

1. Futures. Create a technology roadmap and forecast; identify potential observables to aid in the tracking of technological advances.
2. Technology Watch. Monitor (global) communications and publications for breakthroughs and integration.
3. Technology Warning. Positive observables indicate that a prototype has been achieved.
4. Technology Alert. An adversary has been identified and operational capability is known to exist.²⁵

The report indicates that the last two categories are the more important of the four indicators requiring attention at the national level.²⁶

The final category is Consequence. This area attempts to answer the question, *“What is the impact on military capability should the technology be employed by an adversary?”*²⁷ The committee assesses each technology as a RED implementation against BLUE forces. This area attempts to determine the scope of the disruptive technology implementation from —...single person, ...or creates a circumstance of mass casualty and attendant mass chaos.”²⁸

The Committee on Defense Intelligence Agency Technology Forecasts and Reviews arrived at three findings:

1. There is a multitude of evolving technologies for which advances are being driven by nongovernmental, global, scientific, and technical communities.
2. New intelligence indicators are likely to be needed to provide technology warning for the diverse spectrum of evolving technologies that are being driven by commercial forces in the global marketplace.
3. The landscape of potentially important evolving technologies is both vast and diverse. A disciplined approach is thus needed to facilitate optimal allocation of the limited resources available to the technology warning community.

In finding 1, they state, ~~the~~ information technology, biotechnology, microtechnology, and nanotechnology families will increasingly provide foundational building blocks for military relevant capabilities for RED (adversary) and BLUE (U.S.) forces alike.”²⁹ Advances in potential disruptive technologies will be driven primarily by commercial demand instead of military-specific requirements.³⁰ They recommend that

the intelligence community should continue a collaborative relationship with the scientific and technical communities and focus on technology warning.³¹

In finding 2, the committee recognizes the United States' lead in science and technology which grants a special position of being able to look for external actors attempting to develop new technologies or exploit known technology in new ways.³² They recommend that the ~~intelligence~~ intelligence community establishes, maintains, and systematically analyzes a comprehensive array of indicators pertaining to globalization and commercialization of science and technology.”³³

The committee also recognizes how easy it is to create lists of technologies that will develop in the next 20 years, however, it is harder to create a list of specific technologies that will be ~~potential~~ “potential game-changers” or disruptive in the hands of adversaries.³⁴ They identify that the some of the technology that will be developed will be disruptive while others will diminish the technological edge that the United States enjoys.³⁵ The committee recommends a disciplined approach to a ~~capabilities~~ capabilities-based framework...to identify and assess potential technology-based threats.”³⁶

In the conclusion statement, the CDIATFR identifies the importance of the technological warning community and stresses that BLUE forces capabilities are intrinsically linked to technology. They say that while the U.S. still has the technological edge, new ~~building block~~ “building block” technology is becoming increasingly available from the commercial marketplace and tracking acquisition by foreign governments and third-party actors is a hard feat.³⁷ Nonetheless, tracking and warning is very important.

The CDIATFR report noted that in 1953, when the federal government supported a majority of the research and development conducted in the United States, the federal

government has lost the lead as the primary funder for this research. By 2003, the federal government has fallen to about 30% of research and development funding in the United States with private industry taking a majority of the other 70% of funding per year.³⁸

Finally, the committee report focused on disruptive technologies in four areas: Information superiority, Air superiority, Discrimination between friends, foes, and neutrals, and Battle readiness and communications superiority.³⁹ Within these four areas, the committee evaluated over forty potential disruptive technologies. In addition, they identified tiers for technologies that should be watched up to 2015 (figure 5).

BOX 1-1
Candidate Technologies Likely to Impact National Security by the
2015 Time Frame, Identified by a Panel of Experts

First Tier: High-Impact Technologies

- Gene Therapy
- Wireless Communications
- Image Understanding
- Cloned or Tailored Organisms
- MicroElectroMechanical Systems (MEMS)
- Nanotechnology

Second Tier Technologies

- Optical Communications
- Regenerative Medicine
- Efficient Software Development
- Sensor Webs
- Advanced Materials

Third Tier: Below-Threshold Technologies

- Hypersonic/Supersonic Aircraft
- Next-Generation Space Shuttle System
- Alternative Energy
- Distributed Energy
- New-Generation Nuclear Power Plants
- Fuel Cells

Other Technologies Considered

- Brain-Machine Interfaces
- "Smart" Materials (organic and inorganic)
- Distributed-Grid-Based Processing Systems
- Performance-Enhancing Drugs
- Multilingual Voice Recognition
- Molecular Electronics
- Ubiquitous Water Generation
- High-Power Lasers
- Directed Energy (Microwave)

NOTE: See definitions of these technologies in Appendix C of this report.
SOURCE: OTI IA (2001).

Figure 5. Candidate Technologies Likely to Impact National Security by 2015 Time Frame, Identified by a Panel of Experts
Source: National Research Council, Candidate Technologies Likely to Impact National Security by 2015 Time Frame, Identified by a Panel of Experts, 16.

The Committee on Forecasting Future Disruptive Technologies

The Committee on Forecasting Future Disruptive Technologies commissioned by the Director, Defense Research and Engineering and the Defense Intelligence Agency's Defense Warning Office published its first report, "Persistent Forecasting of Disruptive Technologies" in mid-2009. This report's intent was to clarify a way forward of predicting future disruptive technologies in order to prevent technological surprise and disruption.⁴⁰ This report assessed current technology forecasting systems and identified several attributes of a persistent long-term disruptive technology forecasting systems.⁴¹ The report also identified the difficulty of forecasting potential disruptive technologies because the general nature of disruptive technology is that it arrives abruptly and infrequently, and are therefore particularly hard to predict using an evolutionary approach."⁴²

This report broke the analysis and forecasting of disruptive technologies into the following areas:

1. Data Sources. Data must come from a diverse group of individuals and collection methods, and should consist of both quantitative and qualitative data.
2. Multiple forecasting methods. The system should combine existing and novel forecasting methodologies that use both quantitative and qualitative techniques.
3. Forecasting team. A well-managed forecasting team is necessary to ensure expert diversity, encourage public participation, and help with ongoing recruitment.

4. Forecast output. Both quantitative and qualitative forecast data should be presented in a readily available, intuitively comprehensible format.
5. Processing tools. The system should incorporate tools which assess impact, threshold levels, and scalability; detect outlier and weak signals; and aid with visualization.
6. System attributes. The system should be global, persistent, open, scalable, and flexible with consistent and simple terminology, support multiple languages, include incentives for participation, and be easy to use.
7. Environmental considerations. Financial support, data protection, infrastructure support, and auditing and review processes must also be considered.⁴³

The CFFDT also identified two classes of disruptive technology. The first class is a technology that is used in a new way to create disruptive results. The second class of disruptive technology is a completely new technology with new effects. The CFFDT also named four attributes of disruptive technology:

1. There is a discontinuity in a plot of a key factor versus time curve such as performance, cost, reliability or any number of characteristics that are used to describe a technology.
2. The disruptive technology impacts other technologies.
3. The birth of many disruptive technologies transcends several disciplines.
4. Leadership, in terms of corporate vision, is the strongest force in promoting the introduction of a new disruptive technology.⁴⁴

Erwin Daneels in *The Journal of Produce Innovation Management* identifies several questions regarding disruptive technology research. Daneels defines disruptive technology as —a technology that changes the bases of competition by changing the performance metrics along which firms compete.”⁴⁵ Daneels raises the question of predictive analysis of potential disruptive technology and how this can be done.⁴⁶ Daneels points out that Christensen has been accused of cherry-picking cases of disruptive technology that support his model.⁴⁷ He also points out some potential disruptive technologies that failed to gain a foothold.

Transformation from Disruptive Technology to Sustaining Technology

The last factor of commercial disruptive technology is its institution as a sustaining technology after its introduction. Thinkers on disruptive technology give two possibilities which happen in the realm of commercial disruptive technology. The first is that the company that develops the disruptive technology will increase market share and, relatively quickly, replace the entrenched technology. The second company will attempt to maintain its customer base, not realizing that the disruptive technology is the new standard and improvement on the entrenched company’s technology. In the first case, the disruptive technology will become sustaining and then follow the improvement pattern of regular entrenched commercial technology.

Invention and Technological Surprise

Black Swans

Nassim Nicholas Taleb first introduced the black swan theory in his book, *The Black Swan: The Impact of the Highly Improbable* in 2007. The basis of the theory is that

before the discovery of Australia, all swans were white based on what was known historically. No one conceived that swans could be any other color than white. As explorers crossed Australia, they discovered the black swan, thus breaking the conventional truth, held for centuries, that all swans were white. The theory of the black swan has three characteristics:

1. It is unpredictable, meaning it lies outside the realm of the predictable.⁴⁸
2. It carries a massive impact.⁴⁹
3. Humankind attempts to create an explanation that makes the event seem less random and more predictable.⁵⁰

This theory is based on mathematical probability theory and its connection to disruptive technology is important. Despite that some military disruptive technology could be considered a black swan, the real importance of the black swan is that humans overestimate what they know and underestimate uncertainty.⁵¹

In his explanation of his theory, Taleb describes an experiment conducted in the 1960s which demonstrates that the more knowledge that individuals have, the more likely they individuals are to theorize about what they know. In this experiment, two groups are shown a blurred picture of a fire hydrant that they could not initially identify. One group was given closer images of the fire hydrant in ten steps and one was given closer images in five steps. The group with only five intermediate steps was able to identify the fire hydrant faster than the group with ten steps.⁵² Essentially, the more information a group were given, the more likely they were going to form theories about what they were looking at and, thus, become entrenched in their theory.⁵³

Technological Surprise

Technological surprise is a term used more and more in conjunction with disruptive technology. Dr. George H. Heilmeier, in his 1976 article, “Guarding Against Technological Surprise,” in *Air University Review*, defines technological surprise as technology “that suddenly thrusts itself on the scene--something that explodes our consciousness rather than evolving in a predictable way.”⁵⁴ Heilmeier’s point about technological surprise is not necessarily who owns and implements the new technology but rather awareness of technology’s impact.⁵⁵ Technological surprise, Heilmeier says, is in many cases, not necessarily entirely based on new technology arriving on the battlefield but rather the use of a technology coupled with new tactics that causes the surprise.⁵⁶

Heilmeier gives seven steps that a society can take to prevent technological surprise:

1. Maintain technological initiative.
2. Ensure that intelligence is timely.
3. Develop options.
4. Develop mechanisms that provide for an orderly response when a technological surprise suddenly appears.
5. Make tactical and doctrinal flexibility part of our training and test and evaluation processes.
6. Create an atmosphere of cooperation and exchange between technologists and commanders of real forces.

7. Make sure that there will be a close working relationship between defense-oriented scientists and engineers and their colleagues in the industrial and in the university technical communities.⁵⁷

According to Heilmeier, these seven steps are essential for a democracy to prevent technological surprise⁵⁸ against the Soviets, the United States primary competitor in 1976.

In 1984, Captain Neal I. Fox, again in the *Air University Review*, warns of the importance of safeguarding against technological surprise. As in Dr. Heilmeier's article, he reached into history to the use of the longbow in destroying the French armored knights and men-at-arms.⁵⁹ Captain Fox emphasized the need to maintain technological superiority over the enemy, whom, at the time, were the Soviets. He also stresses one of the important factors in competition with the Soviets was technological espionage and says that there were over 150 Soviet weapons developed on Western technology.⁶⁰

Motivation to Develop Military-Oriented Disruptive Technology

The motivation to develop military disruptive technology is to gain a strategic advantage or equalization of military forces in the case of asymmetric warfare. The motivation to develop conventional commercial disruptive technology is market and commercial driven. The commercial development and military development of disruptive technology both follow the relatively same rules in prototype development in that they are both developed for “fringe” customers.⁶¹ The development of military disruptive technology is driven by an operational need and sometimes a vision of what the military will need in the future, whereas commercial disruptive technologies are developed by

smaller companies hoping to establish a niche in an established market. In either case, the proven effectiveness of a new disruptive technology must be established before it gains a sustained status.

The Director of Plans and Programs in the Office of the Director of Defense Research and Engineering gave three reasons why disruptive technologies are of interest to the Department of Defense:

1. Understanding disruptive technologies is vital to continued competitive stature.
2. The potential for technology surprise is increasing with increased knowledge in the rest of the world.
3. There is a need to stay engaged with the rest of world in order to minimize surprise.⁶²

The report goes on to quote the four strategies detailed by Pudas in the 2006 Quadrennial Defense Review and reiterate the threat that international competitors are continuing to develop breakthrough technological capabilities to ~~m~~marginalize U.S. military power, particularly in operational domains.”⁶³

Chapter Summary

This chapter provided further definitions of disruptive technology and innovation pre-1995 to describe commercial and military-oriented disruptive technology. It also referenced examples of how disruptive technology is currently being evaluated. This chapter also discussed the impact of randomness and technological surprise as assessed by some authors. Finally, this chapter discussed how and why new technologies are developed and why they are important to the United States.

¹Stephen Peter Rosen, *Innovation and the Modern Military: Winning the Next War*, (Ithaca, NY: Cornell University Press, 1991), 6.

²*Ibid.*, 9.

³*Ibid.*

⁴*Ibid.*, 25.

⁵*Ibid.*, 26.

⁶*Ibid.*, 28.

⁷*Ibid.*, 40.

⁸*Ibid.*, 42.

⁹*Ibid.*

¹⁰John C. Keefe, “Disruptive Technologies for Weapon Systems: Achieving the Asymmetric Edge on the Battlefield,” *The Weapon Systems Technology Information Analysis Center Quarterly* 7, no 4: 3.

¹¹*Ibid.*

¹²*Ibid.*, 6.

¹³*Ibid.*

¹⁴*Ibid.*

¹⁵*Ibid.*

¹⁶*Ibid.*

¹⁷Terry J. Pudas, “Disruptive Challenges and Accelerating Force Transformation,” *Joint Forces Quarterly*, no 42 (3d Quarter 2006): 44.

¹⁸*Ibid.*, 45.

¹⁹*Ibid.*

²⁰*Ibid.*, 46.

²¹Peter Dombrowski and Eugene Gholz, “Identifying Disruptive Innovation: Innovation Theory and the Defense Industry,” *Innovations* 4, no. 2 (Spring 2009): 101.

²²National Research Council, *Avoiding Surprise in an Era of Global Technology Advance* (Washington, DC: The National Academic Press, 2005), 25.

²³*Ibid.*

²⁴*Ibid.*

²⁵*Ibid.*

²⁶*Ibid.*

²⁷*Ibid.*, 26.

²⁸*Ibid.*

²⁹*Ibid.*, 6.

³⁰*Ibid.*

³¹*Ibid.*

³²*Ibid.*

³³*Ibid.*

³⁴*Ibid.*, 7.

³⁵*Ibid.*

³⁶*Ibid.*

³⁷*Ibid.*, 12.

³⁸*Ibid.*, 14.

³⁹*Ibid.*, 27.

⁴⁰National Research Council, *Persistent Forecasting of Disruptive Technologies*, (Washington, DC: National Academic Press, 2009), FR-5.

⁴¹*Ibid.*, S-4.

⁴²*Ibid.*

⁴³*Ibid.*, S-7.

- ⁴⁴Ibid., 3-4.
- ⁴⁵Erwin Danneels, —Disruptive Technology Reconsidered: A Critique and Research Agenda,” *The Journal of Product Innovation Management* (2004): 249.
- ⁴⁶Ibid., 250.
- ⁴⁷Ibid.
- ⁴⁸Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable*, (New York, NY: Random House, 2007), xvii.
- ⁴⁹Ibid.
- ⁵⁰Ibid., xviii.
- ⁵¹Ibid., 140.
- ⁵²Ibid., 144.
- ⁵³Ibid.
- ⁵⁴George H. Heilmeier, —Guarding Against Technological Surprise,” *Air University Review* (September-October 1976), <http://www.airpower.maxwell.af.mil/airchronicles/aureview/1976/sep-oct/heilmeier.html> (accessed October 16, 2009).
- ⁵⁵Ibid.
- ⁵⁶Ibid.
- ⁵⁷Ibid.
- ⁵⁸Ibid.
- ⁵⁹Captain Neal I. Fox, —On Technological War,” *Air University Review* (November-December 1984), <http://www.airpower.au.af.mil/airchronicles/aureview/1984/nov-dec/fox.html> (accessed October 16, 2009).
- ⁶⁰Ibid.
- ⁶¹Dombrowski and Gholz, 102.
- ⁶²National Research Council, *Persistent Forecasting of Disruptive Technologies*, (Washington, DC: National Academic Press, 2009), 1-1.
- ⁶³Ibid.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter addresses trends of potential military disruptive technology being developed from 2000 to 2009. This chapter will address some examples of commercial and military disruptive technology. This chapter will also discuss some of the methodologies and criteria currently used to evaluate and predict future disruptive technologies.

This thesis used quantitative and qualitative research to identify important potential military disruptive technologies that may be developed in the next 20 years. The analysis of two common, United States periodicals, *Popular Science* and *Popular Mechanics*, to show trends of what is being developed and worked on by independent inventors and corporations alike.

Disruptive Technology –Officially” Identified

The two open source reports from the National Academy of Sciences give several areas of identified disruptive technology. In addition, several articles have listed areas of disruptive technology but do not give specifics of what makes the technology particularly “disruptive.” Open source information seems to continuously call laser weaponry, robotics of the aerial and ground variety, nano- and bio-technology advances, and material advances as disruptive technologies. Many authors have created lists of “disruptive” technologies but in many cases, these lists of technological advances may not be disruptive in nature but rather just more efficient ways of conducting operations.

Trends in Disruptive Technology Development

Using the “observable” category of the CDIATFR report, open source information from two common magazines, *Popular Science* and *Popular Mechanics* magazines from 2001 to 2008 were used to determine if there were trends in certain technology sectors. These two magazines conduct inventor contests and showcase many technologies being developed independently. In addition, these magazines generally give short paragraphs on technologies that the military is working on and what the military is expecting to gain from the research and development. *Popular Science* provided a well-rounded look at different industries and science and technology while *Popular Mechanics* focused more on automotive showcases, some military systems and application, and some robotics. These two common magazines were analyzed because of the vast amount of technical literature across several different disciplines.

Based on these two magazines, the trends of potential commercial disruptive technologies showed a pre-dominance toward robotic and aerospace technologies. In addition, many articles about energy and medical advances appeared.

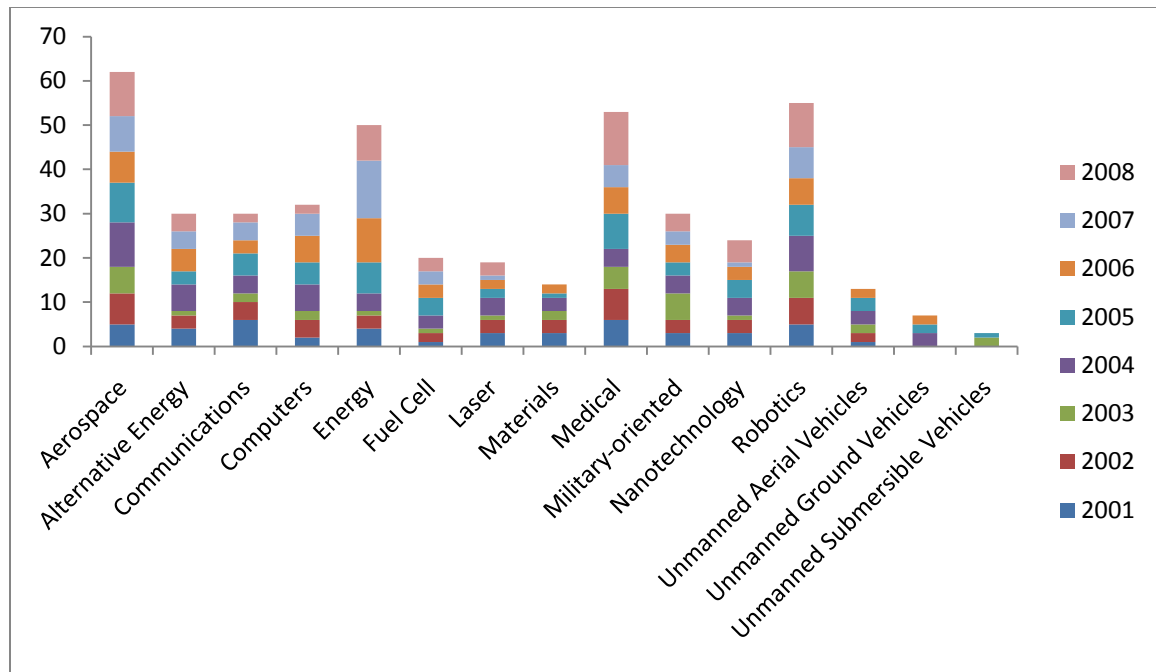


Figure 6. Distribution of Technology Articles appearing in *Popular Science* magazine.
Source: Created by Author.

Almost all of these articles discuss cross-over technologies from other sectors. For instance, important to robotics development is energy, materials, and computing. Important to aerospace are fuel cells, energy, and materials. Unmanned aerial and submersible vehicles crossed into aerospace, robotics, computers, and materials frequently. The energy category was a combination of biotechnology, large scale and small scale waste recyclers, up to refrigerator sized nuclear reactors, and nuclear reactor science projects. Alternative energy was a combination of solar, wind, and biological energy ideas. Lasers primarily crossed when articles were about laser mounted air and ground systems, however, there were one or two articles about superheating materials and manipulation of light beams that fell into this category. Medical crossed into several fields, specifically, nanotechnology, biotechnology, lasers, robotics, communications,

aerospace, and military-oriented applications. The dominance of aerospace in this study is due to the X-prize suborbital flight contest and showcases or information on the F-22 and F-35 fighters that the military was acquiring. However, not uncommon in the gamut were articles showcasing man-interface flight apparatus such as rotor wings and jet packs. Computers crossed into energy, nanotechnology, robotics, aerospace, medical, and communications. Communications crossed into energy, medical, nanotechnology, and military-oriented categories.

In the last few years, robotics, medical, energy, and aerospace seemed to take the majority of the articles, large or small. Approximately half of the robotics, and aerospace articles were in reference to specific military application. About a third of the medical articles were in reference to combat medical issues such as head trauma, loss of limb or eyesight, or paralysis robotics or cybernetics.

Not included in this because of an incomplete year were the 2009 articles. However, the trend in 2009 was toward robotics, specifically unmanned vehicle and weapon systems, and combat exoskeleton showcases. Two other high trends were nanotechnology and medical areas.

Robotics

The area of robotics is divided into three areas: unmanned controlled vehicles of aerial and ground variety, unmanned autonomous vehicles of aerial and ground variety, and combat robotics. The unmanned controlled vehicles are things such as unmanned aerial vehicles and ground explosive ordinance removal. Unmanned autonomous vehicles are robots that use semi-artificial intelligence with rule sets to conduct certain operations without interaction from human operators. Combat robotics are further broken into two

sub-categories: autonomous or controlled robots with weaponry attached and military exoskeleton technology. None of these robots fall into the nanotechnology category.

Robotics research for prosthetics and non-military requirements is funded primarily by commercial institutions and research colleges. However, military needs have been primarily sponsored by governments. Several articles in *Popular Science* and *Popular Mechanics* magazines have showcased robots rigged with weapons over the previous eight years, specifically after the beginning of the Global War on Terrorism. The Israeli's developed a small robot mounted with an Uzi machine gun.¹ The United States fielded three Special Weapons Observation Remote Direct-Action System (SWORDS) in June 2007.² However, the article failed to say whether or not the robots had been used against human adversaries. Geoff and Mike Howe were recognized in the June 2009 *Popular Science* magazine for their Ripsaw unmanned ground vehicle.³ The speculation in the article was that with only a few more modifications to the chassis, the robot could mount a weapon system and surveillance systems for advance reconnaissance.⁴ These three articles show that the technology is viable and being built by independent inventors as well as government sponsors. The United States has embraced the armed robot technology by ordering 1700 Lockheed Martin Multifunction Utility/Logistics and Equipments (MULEs).⁵ According to the article, delivery is scheduled for 2014 and half will be armed with four Javelin missiles and a M240 machine gun.⁶ The same article also showcased the Modular Advanced Armed Robotic System (MAARS) and the Warrior X700, both of which are mounted with machine guns. The January 2008 issue of *Popular Mechanics* also showcased the MAARS.

On the commercial side, the Defense Advanced Research Projects Agency launched a \$55 million project to build better bionics in 2007. The specific requirement of the project was to create a bionic arm that could respond to thought control.⁷ However, further cursory web searches about the DARPA bionic arm in October only yielded one article which discussed most of the similar information in the previous article. Robot exoskeleton legs developed by Arnit Goffer were presented in the June 2009 *Popular Science* magazine. The intent of the legs is to help paraplegics walk with simple controls and upper body motions.⁸

Lasers and High Energy Weapons

Beam weapons have been in the imagination of science fiction writers since the beginning of the science fiction genre. They gained their prevalence as the weapon types that aliens would use against the standard military weapons of the 1950s-1990s. In most of the movies, there was always an asymmetrical way that the less powerful military would defeat the technological superior aliens. However, since the invention of the laser in 1960 by Theodor Maiman, it has been improved upon in science, medicine and technology. The laser is used extensively in the medical profession as the new cutting tool. The military disruptive technology aspect of the laser is its use as a weapon.

Several articles discussed the latest testing of lasers in commercial and military application. Boeing demonstrated a solid state 1-Kilowatt laser mounted on a Humvee to destroy explosive threats in September 2007.⁹ A year later, the contract for further development was under bid by Boeing and Northrop Grumman.¹⁰ The United States Navy is pursuing free electron lasers by 2017 as anti-missile and anti-aircraft systems for aircraft carriers.¹¹

Super Soldiers: Medical and Combat Enhancement

The area of combat enhancement is directly derived from sports medicine enhancement with the essence to create athletes that are better and faster with quicker recovery times. In the Steven Kotler's *Popular Science* article, "The Future of Sports Enhancement: Juicing 3.0" several new medical technologies to enhance athlete performance were outlined with their effects and timeline for potential widespread distribution. However, most of the drugs outlined have been tested by the Food and Drug Administration and the reports are based on research done by the author.

There are several drugs which are currently available that could enhance athletic performance through "neural enhancement."¹² Neural enhancement includes boosting dopamine, norepinephrine, and serotonin levels. Increased serotonin is thought to increase positive mood while dopamine and norepinephrine seems to increase motor control and muscle control.¹³ Currently, these drugs are in their first generation and the expectation is that they will reach second generation effectiveness in three years.¹⁴

Almost all athletes spend time in the gym to increase their muscle mass. The second subject examined by Kotler is that turning off the protein myostatin may cause increased muscle growth. Kotler cites research conducted at John Hopkins University by Alexandra McPherron and Sie-Jin Lee that when the protein myostatin is turned off in laboratory mice, the size of the mice muscles doubled.¹⁵ In 2000, a German baby born without the myostatin protein exhibited extremely overdeveloped muscles.¹⁶ The article suggests that myostatin blocking drugs could be on the market within five years.¹⁷

In pursuit of the stronger body, gene doping the next area that Kotler discusses. While gene doping has been used particularly to treat infants with immune-deficiency

syndromes, there were some severe side effects like leukemia.¹⁸ Kotler names the supposed effect of the Repoxygen virus to increase the production of oxygen-carrying blood cells in humans.¹⁹ The athletic effect is to increase oxygen flow to muscles which increases performance. Kotler suggests that gene doping will be far more prevalent by the 2012 Olympic games but that real refinement of gene doping technology is about five years away.

Stem cell research has undergone a furious moral debate within the United States in the last ten years. The use of stem cells to bulk up or repair bodies is the next technology that Kotler discusses. From the sports perspective, this medical technology is considered cheating.²⁰ Stem cell research has shown that it can stem cells can form muscle, however, the technology has not developed to a degree to cause stem cells to build the right muscle or develop additional functions.²¹ The technology has a potential of breakthrough in the next ten years.

The last subject that Kotler talks about in his article is the natural high or “in-the-zone” feeling that athletes sometimes experience during games. Dopamine is again listed as a drug that “increases muscle reaction time speed and alters the perception of time.”²² The article says that in 2004, Arne Dietrich, a neuro-scientist at the Georgia Institute of Technology, believes that anandamine is the chemical —mostlikely responsible for flow states.”²³ The article also talks of endorphins and the current theory is that anandamine is the chemical that helps endorphins move in the brain.²⁴ This technology has been studied for at least 30 years and the prediction on a breakthrough is another 15 years.

The powered armored suit for combat enhancement was completely science fiction in the 1950s. The technology simply did not exist. However, Gregory Mone’s

article, “Man of Steel,” in the May 2008 issue of *Popular Science*, updates the readers on the current state of exoskeleton technology. According to the article, the Defense Advanced Research Project Agency, has been funding exoskeleton research since 2000. The outcome of the research is Raytheon Sarcos’s XOS exoskeleton.²⁵ While Raytheon Sarcos won the contract bid to further develop the XOS exoskeleton for military use, other companies in the competition have taken the exoskeleton to more commercial uses. The XOS exoskeleton allows its wearer to conduct repetitious high weight exercises and complex movements which demonstrate its strength and mobility.²⁶ The XOS exoskeleton in the article did not have internal power. The predictive nature of the article lists several technologies to be integrated into the exoskeleton by 2020:

1. 2008--Self-contained battery-powered system that powers itself with each step of the suit.²⁷
2. 2009--Automated and quick function change actions which allow the user to either enter or exit the suit quickly or provide a boost of power for movement.²⁸
3. 2010--Evacuation and carry system that attaches to the suit. The current suit can already carry a 190-lb man on its back.²⁹
4. 2013--Internal data monitoring, system status, and communications rig for an enclosed helmet.³⁰
5. 2013--Increased running speed beyond the current suit speed of 6 miles per hour.³¹

6. 2015--Weapon and odd job handling which allows the user to use the strength of the suit to do tasks like handling two-man heavy weapons or heavy equipment repair.³²
7. 2018--Increased strength using polymers which, when electrically charged produce 100 times the force of natural muscle.³³
8. 2018--Bulletproof material that is lightweight and strong for the outside of the exoskeleton.³⁴
9. 2018--Heals wounds by delivering a blood clotting agent as well as monitor the health of the soldier.³⁵

Previously Evaluated Disruptive Technologies

Loosely, the CDIATFR identified several technologies likely to impact national security by 2015 and most can be broken down into five areas of potential disruptive technologies:

1. Medicine.
 - a. Gene Therapy.
 - b. Cloned or Tailored Organisms.
 - c. Regenerative Medicine.
2. Aerospace.
 - a. Hypersonic/Supersonic Aircraft.
 - b. Next-Generation Space Shuttle System.
3. Energy
 - a. Micro Electro Mechanical Systems.
 - b. Alternative Energy.

- c. Distributed Energy.
 - d. Fuel Cells.
 - e. New-Generation Nuclear Power Plants.
4. Computer Programming or Software
- a. Image Understanding.
 - b. Efficient Software Development.
 - c. Distributed-Grid-Based Processing Systems.

The CFFDT was primarily focused on the evaluation methodology of disruptive technology and only used technological case studies in their report. The CFFDT discussed three methodologies and their strengths and weaknesses in forecasting potential disruptive technologies.

Delta Scan is a forecasting tool developed by the United Kingdom which focuses on technological developments. This system collects information from over 250 experts in government, business, academia and communications through workshops, interviews and wikis.”³⁶ The outcomes of the information pull are single sentences which provide possible outlooks for the future. This approach is funded by British government with the intent to forecast potential disruptive technologies for which it must be prepared.

The CFFDT finds the major strength of the Delta Scan as —its goals, process and approach were defined from inception.”³⁷ The collection of information from experts and panels of professionals help develop the forecast which makes it reasonably strong. However, the weakness of the forecast is that it focuses on local rather than global information³⁸ and lacks support for non-English language data pulls.³⁹ The last major problem is that the forecast focuses on well-known technologies and not second order

effects or combinations of these well-known technologies to predict a new disruptive technology.⁴⁰

TechCast, a system developed by William E. Halal at George Washington University, scans sources to find technology topics of interest to forecast.⁴¹ Then one hundred experts are surveyed on the topics of their expertise and a report is created on an ad hoc basis.⁴² The prediction covers whether the technology will reach adoption, the scale of market impact, and the expert's confidence in his or her forecast.⁴³ This methodology is considered persistent as each new input updates the forecast. The benefit is that the forecast covers at least 70 technology areas.⁴⁴

The CFFDT considers the flexibility of the platform, the wide range of prediction needs and its simplicity as TechCast's primary strengths.⁴⁵ The clarity of the output and the four step process and minimum number of resources required to run TechCast are also noted. The weaknesses that the CFFDT notes are the dependence on administrators to select the topics for expert commentary. In addition, the output of the system is highly influenced by the composition of the expert pool and the criteria for inclusion into that pool is unclear.⁴⁶ In addition, the system does not track other potential indicators of disruptive technology such as signals, signposts, or tipping points.⁴⁷

The X2 project, also known as Sigtific, developed by the Institute for the Future collaborates information from social networking sites, futurism and forecasting.⁴⁸ This system also uses workshops, online wiki-based platforms, and alternate reality games to produce forecasts.⁴⁹ The analysis by the CFFDT describes three components of forecasting development. The first component is the use of expert workshops held worldwide which consisted of a theme, futures and geographies of science, and a

breakout to develop instances of future possibilities.⁵⁰ The second component of X2 was an online platform which allowed experts to post signal of interest to specific subject groups.⁵¹ Experts were then allowed to comment on the likelihood and potential impact of any signal generated from the online platform.⁵² The final outcome of the online platform is the generation of perspectives on the future.⁵³ The last component of the X2 system is ~~an~~ alternative reality games to flush out an alternative future.”⁵⁴ These games are guided by a game master who generates events and monitors the scenario. Outside discussion by the game participants helps the development of the scenario and its outcomes.

The CFFDT considers the X2 forecasting method to be innovative in its methodology and lauds the gaming environment to bring more players into its alternative reality games to help flush out potential disruptive technologies. Despite the innovations in the X2 system, the CFFDT felt that the limitation to English and a lack of diversity of participants in the workshops and locations were shortcomings of the method.⁵⁵

The CFFDT developed an extremely long list of categories, attributes, and descriptions as components of an idea forecasting system. In the committee’s final conclusion, they determine that it is possible to forecast a disruptive event with information available but they can be missed because of several reasons.⁵⁶ The committee believed that it is possible to develop a persistent forecasting system which can reduce the uncertainty and surprise.⁵⁷

Chapter Summary

This chapter showed trends of technology development as seen through commercial technology publications. In addition, it provided information on a few

predominant technology areas that will most likely come to fruition within the next 20 years. Finally, this chapter discussed the current data-mining methodologies to develop disruptive technology forecasts in the next 20 years.

¹Erin McCarthy, “Israeli Military Robot is Built to Kill (Mini-Uzi Included),” *PopularMechanics*, June 2007, http://www.popularmechanics.com/technology/military_law/4216523.html (accessed April 7, 2009).

²Erik Sofge, “The Inside Story of the SWORDS Armed Robot –Pullout” in Iraq: Update,” *Popular Mechanics*, April 15, 2008, http://www.popularmechanics.com/blogs/technology_news/4258963.html (accessed April 7, 2009).

³Bjorn Carey, “The Fastest Tank,” *Popular Science*, June 2009, 38.

⁴*Ibid.*, 39.

⁵Erik Sofge, “America’s Robot Army: Are Unmanned Fighters Ready for Combat?” *Popular Mechanics*, March 2008, http://www.popularmechanics.com/technology/military_law/4252643.html (accessed April 7, 2009).

⁶*Ibid.*

⁷Bjorn Carey and Michael Belfiore, “Bionic Made Better,” *Popular Science*, September 2007, 36.

⁸Gregory Mone, “Robo-Legs,” *Popular Science*, June 2009, 46.

⁹Joe Pappalardo, “Lasers Get a Shot at IEDs,” *Popular Mechanics*, February 2008, 18.

¹⁰Erik Sofge, “Laser Truck Inches Closer to Iraq Battlefield: Exclusive First Look,” *Popular Mechanics*, July 22, 2008.

¹¹Lawrence Schuette, “Naval Innovation and Disruptive Technology,” Office of Naval Research, September 5, 2007. Powerpoint.

¹²Steven Kotler, “The Future of Sports Enhancement: Juicing 3.0,” *Popular Science*, August 2008, 38.

¹³*Ibid.*

¹⁴*Ibid.*

¹⁵Ibid., 40.

¹⁶Ibid.

¹⁷Ibid.

¹⁸Ibid.

¹⁹Ibid.

²⁰Ibid., 41.

²¹Ibid.

²²Ibid.

²³Ibid.

²⁴Ibid.

²⁵Gregory Mone, “Man of Steel,” *Popular Science*, May 2008, 45.

²⁶Ibid., 46.

²⁷Ibid., 49.

²⁸Ibid., 48.

²⁹Ibid., 49.

³⁰Ibid., 48.

³¹Ibid., 49.

³²Ibid., 48.

³³Ibid., 48.

³⁴Ibid., 49.

³⁵Ibid.

³⁶National Research Council, *Persistent Forecasting of Disruptive Technologies*, (Washington, DC: National Academic Press, 2009), 6-1.

³⁷Ibid., 6-4.

³⁸Ibid.

³⁹Ibid.

⁴⁰Ibid., 6-5.

⁴¹Ibid.

⁴²Ibid.

⁴³Ibid.

⁴⁴Ibid.

⁴⁵Ibid., 6-9.

⁴⁶Ibid.

⁴⁷Ibid.

⁴⁸Ibid., 6-10.

⁴⁹Ibid.

⁵⁰Ibid., 6-11.

⁵¹Ibid., 6-12.

⁵²Ibid.

⁵³Ibid., 6-13.

⁵⁴Ibid.

⁵⁵Ibid., 6-14.

⁵⁶Ibid., 7-6.

⁵⁷Ibid.

CHAPTER 4

ANALYSIS

This chapter will analyze the findings of the research conducted into how military-oriented disruptive technology is identified and evaluated. This chapter will also address what military disruptive technology is and differentiate it from other areas. This chapter will develop the stages of military disruptive technology. This chapter will also discuss and expand on evaluation metrics currently used and how they must be addressed in light of possible new unforeseen disruptive technologies to prevent technological surprise. Finally, this chapter will discuss the importance of the evaluating disruptive technologies from a military standpoint aside from the intelligence community's identification to prevent technological surprise.

Disruptive technology has been used indiscriminately with no differentiation between military -oriented disruptive technology and commercial disruptive technology. Throughout the research, there have been very poignant examples of military-oriented disruptive technology being developed without a commercial, market-driven requirement. Similar to the development of infra-red night vision capability for the military which had no real commercial application at development, two clear examples of military-oriented disruptive technologies are the development of lasers as weapon systems and the development of robotics as load-bearing and weapon-bearing systems. This places military-oriented disruptive technology into a category separate from the commercial disruptive technology rule sets. Military-oriented disruptive technology must be given a name which distinguishes it from commercial disruptive technology. Therefore, military-oriented disruptive technology can simply be called military disruptive technology.

What Is and Is Not Military Disruptive Technology

Disruptive Technology versus Disruption Technology

Disruption technology is technology which increases the uncertainty or “fog of war” for an adversary. Disruption technology is not necessarily disruptive technology. While disruption technology may change some tactics, techniques and procedures at the tactical and operational levels of warfare, it does not necessarily change warfare at the strategic level of war. Disruption technology can be divided into several areas. Physical disruption technology is technology such as camouflage or camouflage netting. Electronic disruption technology is technology classified for non-cyber electronic warfare. Network disruption technology is technology used for cyber network attack, defense, and delay. The first two categories of disruption technology lend themselves to military disruptive technology advances but are not necessarily disruptive technologies. The last disruption technology is part of the new cyberspace battlefield and though there are innovations that may occur in this area, it is not necessarily military disruptive technology. An example of a simple current disruption technology is camouflage with the tactical advantage of concealing a soldier or a headquarters from an adversary. An example of a future disruptive technology that is also disruption technology is nanotechnology paint that changes colors to match its surroundings or even refracts surroundings to make the equipment appear to be “invisible.”

Cyberspace and Space

Cyberspace and Space are two new dimensions on the battlefield and though those areas will see new disruptive and disruption technologies, they are not, in and of themselves, disruptive technologies. However, there is one key difference between space

and cyberspace as areas of new disruptive and disruption technology; very few nations have access to space while anyone with a cheap computer and very limited financial assets can enter cyberspace and conduct disruption operations. While anyone can design and build a weapon for use in space, the actors that are able to install and use the weapon must have access to space. However, a weapon designed to attack space-based assets should be considered a military disruptive and disruption technology. The actors that have access to space at this time closely control what goes into orbit. An example of a disruptive technology that is used in space is a high energy laser that can strike any location within the arc of its pivot. Almost exclusively, cyberspace is the realm of disruption technology in the next 20 years; however, one example of a disruptive technology used in cyberspace would be an artificial intelligence code breaker used to hack computer systems for access.

Asymmetric Warfare

Asymmetric warfare is between powers whose military power is significantly different. Today, the global war on terror is considered to be asymmetric warfare because the United States enjoys significant technological advantage and power projection that terrorist organizations do have. The tools of asymmetric warfare are not necessarily disruptive technology. As seen during the conflicts in Vietnam, Iraq and Afghanistan, the enemy employed and is employing low-technology, low-cost instruments in an attempt to grind down national will as well as reduce the United States' technological advantage. While this does affect the tactical to operational levels of war, in almost all cases of asymmetric warfare, there is nothing disruptive about the technology being used. The technology and its' use may fall into the realm of military innovation on the asymmetric

battlefield. One case of a low-technology, low-cost instrument that is disruptive technology is the rudimentary electromagnetic pulse generator identified by the CDIATFR.

Space remains the high ground in asymmetric warfare because as stated before, only a few nations or corporations have access. However, the gap is closing as several corporations are working to develop commercial space flight which inevitably leads to more super-empowered groups and individuals gaining the technology to enter space. Working spacecraft that enter suborbital and eventually orbital altitudes that become commercially available effectively makes the entire world smaller. The development of commercial space flight and spacecraft piloting training available to non-government entities will significantly change this front in full spectrum operations. With only a little imaginative extrapolation, disruptive military innovations and technologies available could cause a dramatic change in strategic, operational and tactical operations in the next 20 years.

Several authors consider the technological advantage that the United States enjoys in asymmetric warfare as disruptive in nature. This is true when using high technology against low technology; the equivalent of a machine gun against a population with no technological capability to develop gunpowder weapons. However, when faced with a country with similar technological capability, military disruptive technology is the technology that provides strategic advantage over its adversary.

Military Innovation versus Military Disruptive Technology

Military innovation is a change in tactics or using developed weapons of war in new ways. Military disruptive technology is not necessarily military innovation. This

argument can be made of the longbow at Agincourt because the longbow was in use prior to Agincourt. However, the difference of Agincourt is that following that battle, a new respect was given to the longbow, as well as the implementation of the longbow as an equalizer against armored knights and men-at-arms as the first line of offense or defense in future battles during the Middle Ages.

The Stages of Military Disruptive Technology

Throughout the research, common factors became apparent as to what the stages of a military disruptive technology actually are. There are six stages of military disruptive technology:

1. Cognitive ability to imagine the military disruptive technology or innovation.
2. Intellectual, political, and financial effort to engineer the military disruptive technology into existence secretly or otherwise.
3. Application of the military disruptive technology against an adversary.
4. Development of counter-military disruptive technology by adversaries.
5. Adoption of counter-disruptive technology or the military disruptive technology itself.
6. Stalemate of adversaries using military disruptive technology.

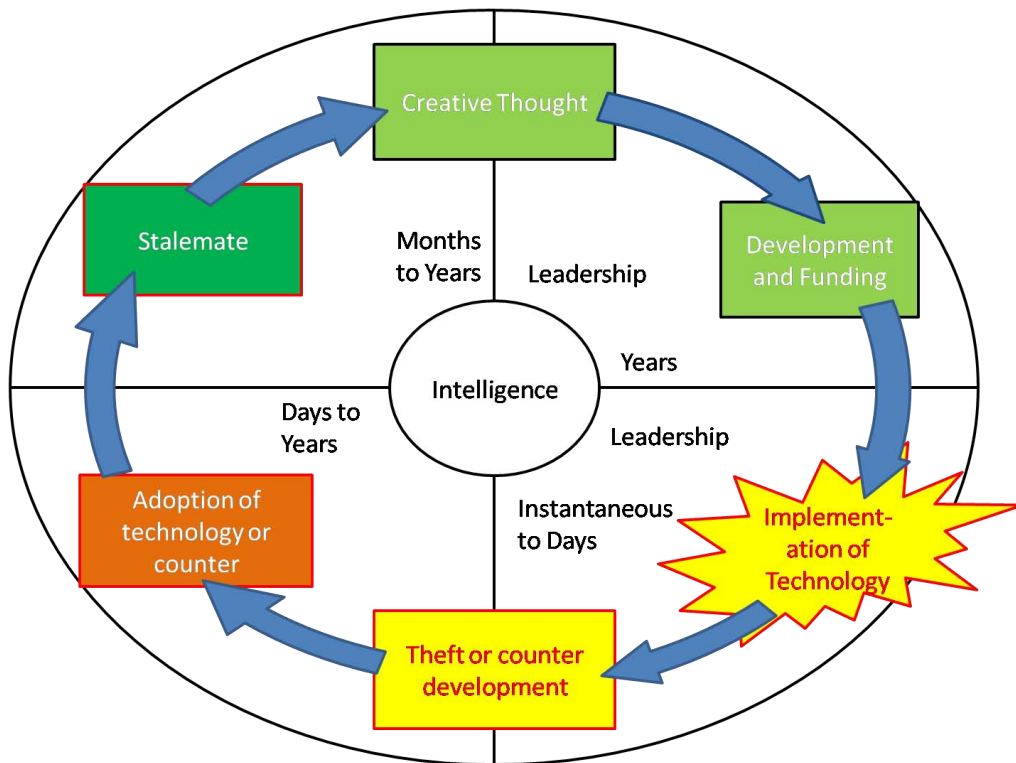


Figure 7. Stages of Military Disruptive Technology
Source: Created by Author.

The first stage of military disruptive technology can be generated from any aspect of society, research, or science fiction. Once the mind begins ruminating on an idea, inevitably, there will be someone who will try to create it. Research can be done in secret, however this is generally counterintuitive to the development of a disruptive technology. As the CDIATFR and the CFFDT state, open source and collaboration is required to generate ideas and their viability. The first two stages are generally lengthy because of political and military whims as well as the motivation to support the “fringe” military customer.¹ However, the difference between the commercial technology development cycle and the military disruptive technology cycle is that there are some technologies which have no immediate non-military commercial value in the marketplace. Because of

this, military disruptive technologies must sometimes be driven by the operational needs of the military customer vice a large commercial customer base. A subsection of stage 2 is distribution of the disruptive technology to those who can use it as Keefe states.² The first two stages of military disruptive technology can be conducted in secret to allow maximum impact in stage three. The problem is that once the tested and the effective disruptive technology has been developed, manufactured, and distributed, the ability to keep the disruptive technology a secret diminishes greatly.

In stage three, the developer of the disruptive technology will use the military disruptive technology to maximum effect. The intent in stage three is to stun the enemy long enough to enable further conventional tactical advantage or even as much as capitulation if the military disruptive technology is devastating enough. This specifically draws from the surprise principle of war.³ The implementation of the disruptive technology amounts to technological surprise against the adversary and it is important to maintain this technological surprise as long as possible. Depending on the secrecy of the development and the devastation of the disruptive technology, stage three could last days, weeks or longer.

Once stage three has been implemented, adversaries will immediately move to stage four. They will inevitably strive to gain an example of the disruptive technology either covertly or off the battlefield. Gaining an item of disruptive technology will help in developing a counter to the implemented disruptive technology, however, it is not necessarily essential. All adversaries and observers will immediately apply intellectual resources to develop a similar, better or counter disruptive technology with the intent of application against the first-user. This stage could last weeks, months, or never be

accomplished by the adversary of the first-user. However, this stage will aggressively be pursued by observers and may be completed fast enough to move to stage five.

In stage five, adversaries and observers, will either adopt, develop, or steal and reverse engineer a similar disruptive technology or innovation. If they do not do this, they risk no longer being able to compete militarily with the first-user. This is a delicate area because the question of how long a first-user wishes to be ahead of its allies in this area of disruptive technology could strain political relations with those allies once they see the effectiveness of the new disruptive technology. Stage five and stage six are the equivalent of the disruptive technology becoming sustaining technology as Christensen states in the market driven version of disruptive technology. This stage could last weeks, months, or years.

Stage six assumes that the disruptive technology or counter-disruptive technology has been adopted by adversaries and allies. At this point, the disruptive technology may transition in terms to a military innovation and sustaining technology because of its adoption by all as well as duplication and improvement on the original disruptive technology. This stage will see the refinement and update of tactics and counter tactics as well as implementation of new tactics, techniques and procedures seen similarly when combating improvised explosive devices and vehicle-borne improvised explosive devices in Iraq. In addition, the world will debate the ethics of this disruptive technology and perhaps even adopt changes to the laws of war and Geneva Convention. This stage will last weeks, months, or years possibly spanning to decades if the disruptive technology is effective enough.

After the new disruptive technology has been adopted or countered by adversaries and allies, the cycle begins again at stage one. A new disruptive technology cycle begins based on the changed battlefield conditions of the disruptive technology introduced during the previous cycle. Doctrine changes and the adopted disruptive technology becomes sustained disruptive technology.

Throughout the first two cycles, leadership plays a significant role in adoption of specific disruptive technologies ideas and governmental or corporation development. However, this does not preclude individual inventors or small groups from working on disruptive technology ideas of their own volition. Leaders provide the organizational input to pursue disruptive technologies of which they are the champions.

A point to note is that this cycle omits the possibility of a black swan or singularity event during development. As stated before, black swan is a completely unpredictable event that is later rationalized to seem like it is less random. A singularity event is an event that is a sudden invention breakthrough in technology that leaves humans behind. The most important part of both of these possibilities is whether the black swan or singularity can be reproduced to enable it to eventually become a sustaining military technology. The importance of both of these events cannot be discounted because once the new disruptive technologies are introduced in the commercial market or on the battlefield, they become technologies available to friends and foes alike to springboard to additional technological surprise.

Effectiveness of the Implementation of a Potential Military Disruptive Technology

This section discusses the extrapolation of the effectiveness of disruptive technologies in reference to what is known today on the battlefield. As warfare has developed over the centuries, the primary branches of infantry, cavalry, and artillery played a dominant role as the primary formations. As the tools of combat have evolved, the innovations and improvements for almost every weapon or piece of equipment were developed as a counter to a technology present on the battlefield. Air power became a primary branch added to its precursors opening a third dimension to the battlefield. Over the ages, it has been a military “rock-paper-scissors” of weapons, armor, tactics and new ideas. As extrapolation implies, logical thought must be employed in an attempt to evaluate a potential military disruptive technology from both a RED and BLUE force perspective. The difficulty in the development of measures of effectiveness for military disruptive technology is to attempting to foresee what might arise on the battlefield which excludes the “black swans” of the highly improbable.

Potential military disruptive technologies can appear in a variety of technological areas which must be evaluated in terms of their engineering or scientific base. However, this characteristic of civilian disruptive technologies makes them difficult to evaluate is that they tend to create a new unforeseen standard or application. This characteristic will most likely be true of new military disruptive technologies as well. Thus the measure of effectiveness metrics must be reviewed intermittently to determine if the correct performance metrics are being measured in terms of new military disruptive technologies. If this is not done, then it is quite possible that a new military disruptive technology may be discarded or not considered in its tactical, operational or strategic application properly.

Measures of effectiveness metrics have traditionally relied on scientific or engineering principles which are proven. A typical example is the “rolled homogenous armor” concept developed to evaluate against anti-tank weapons.⁴ This is the standard used when developing armor for vehicle as a measure of effectiveness against anti-tank weaponry. All materials used for plating military vehicles are given a rolled homogenous armor rating. This measure of effectiveness is valid for conventional munitions but does not necessarily answer the survivability question in the face of potential military disruptive technologies in the next 20 years. This evaluation method automatically focuses armor developers into an anti-kinetic plating solution which precludes other ways of increasing survivability not tied to rolled homogenous armor.

In the case of armor plating, the question which must be introduced in light of military disruptive technologies in the next 20 years is, “What is the best way to prevent kinetic destruction or penetration?” or “What new technology increases survivability of a tank?” These are only two question examples, but they open up alternative engineering or mechanical solutions that can solve the tank and soldier survivability problem. Examples of alternative engineering solutions are reactive armor or even the cages used on Stryker vehicles in Iraq to break up the shaped charges of anti-tank weapons. Examples of potential alternative engineering solutions in the realm of military disruptive technology are microwave or anti-ballistic laser systems which superheat the charge causing it to either detonate prematurely, nullify or diminish their effectiveness.

As soldiers are generally considered the most important resource to an army, a question of soldier survivability must always be considered with the introduction of new military disruptive technology for both BLUE forces and RED forces. The effectiveness

of a new military disruptive technology must address the question, “What is the impact on BLUE force soldiers if used against them?” In the United States use of a military disruptive technology the question becomes, “What is the impact on RED force soldiers if used against them?” The impact of a military disruptive technology when used for offensive or defense for or against BLUE forces and RED is of vital importance when evaluating each technology.

An extremely important question is the morality of the employment of a new military disruptive technology. The United States considers itself a benevolent superpower which is guided by moral rules, whereas, it cannot trust that other nations or actors are guided by such rules. Because of this, the United States cannot discount a potential disruptive technology because it may be immoral if used. The United States must either pursue immoral military disruptive technologies or technologies which could counter their potential effects. This is the only way that the United States can insulate itself from a catastrophic implementation of a potential military disruptive technology against its forces or civilian population.

Potential disruptive technologies are generally given a name, a suspected time of when the technology will emerge, and the effect. Effect on BLUE and RED forces is perhaps the most important part of a new military disruptive technology. However, to enable military leaders to understand how military disruptive technology works in the strategic, operational, or tactical realm, it must be understood as an offensive, defensive, or support capability. This works relatively well when used in conjunction with the current intelligence community’s analysis of commercial disruptive technologies,

however, it falls short in the case of unforeseen glomming of multiple feeder technologies for military disruptive technologies.

Analyzing commercial disruptive technologies is usually done by corporations and how it affects their production and profits. Generally, a company will not place as many resources toward a new disruptive technology because it remains loyal to its customer base and because the disruptive technology is not proven. As military disruptive technology is a special case, analysis of potential military disruptive technology must be determined to be tactical, operational, or strategic in nature. The introduction of military disruptive technology in any of these levels of warfare might have similar effects, the impact in any of these arenas provides different options and effects. Each of these categories of military disruptive technology has its own detriments and advantages when used against or by BLUE forces.

In almost all cases of commercial disruptive technology, the effect of a new disruptive technology is linked to the financial cost, availability to consumers, and additional benefits of the new technology. However, military disruptive technology is different in that almost all foreseeable military disruptive technologies are linked to power storage and generation. In this case, military disruptive technology and commercial disruptive technology are almost intrinsically to the development of new power sources. The Department of Defense, as well as the government of the United States, is pursuing better power generation and storage devices. Almost all foreseeable military disruptive technologies are being kept from the battlefield by current power and energy production capability. Thus, energy and power capability is of vital importance to many new military disruptive technologies and any new military disruptive technologies

must be assessed as relying on the upcoming power generation and storage breakthroughs that will most likely occur in the next 20 years. Failure to assess and understand this will cause the United States to be left behind as new power generation and storage devices become available on the commercial market and therefore, to its adversaries.

For military disruptive technologies, the determination of whether the technology is active or passive is important as well. Active military disruptive technologies almost automatically connote that there is a possible method of detection and defeat mechanism that can be developed. Passive military disruptive technologies require no action by the user of the technology and therefore, may cause adversaries to delay resources in developing a counter to that technology.

Analysis of commercial disruptive technology does not necessarily take into account the glomming of feeder technologies and usually the combination of multiple technologies develop into a disruptive technology. The United States and its military cannot risk unforeseen combination feeder technologies into a new military disruptive technology and must be ahead of adversaries in their predictions. Feeder technologies such as materials, miniaturization , energy and power, computer processing power, and optics are areas that when breakthroughs occur, they will cause ripples which can cause military disruptive technologies to appear seemingly overnight. Advances in individual fields may not cause any new military disruptive technologies to appear, but when used in conjunction with existing or other new disruptive technologies the effects, if unforeseen could be devastating.

Certain technologies currently in development lend themselves easily to extrapolation and measures of effectiveness. Nanotechnology and biotechnology with its

ability to change or manipulate molecules of material has a variety of beneficial and detrimental effects. An easy adaptation of commercial nanotechnology and biotechnology currently being developed to clean oil spills, a seemingly innocuous and “safe” technology, is to adapt it to consume or change fuel types in a given area and then become inert after a certain time. Clearly an offensive weapon when used against an adversary to take away his ability to conduct motorized and mechanized combat operations.

Chapter Summary

This chapter analyzed how military-oriented disruptive technology is currently identified and evaluated. This chapter also distinguished the differences between commercial and military disruptive technology attributes. The stages of the military disruptive technology development was introduced which also demonstrated the importance and significance of surprise upon implementation. This chapter also discussed example metrics used for the evaluation of military technologies that preclude the supposition of other military disruptive technologies that may be overlooked when evaluating them using these metrics. This chapter also discussed the importance of evaluating military disruptive technologies from the military perspective vice a national strategic perspective in order to prevent technological surprise.

¹Peter Dombrowski and Eugene Gholz, “Identifying Disruptive Innovation: Innovation Theory and the Defense Industry,” *Innovations* 4, no. 2 (Spring 2009): 101.

²John C. Keefe, “Disruptive Technologies for Weapon Systems: Achieving the Asymmetric Edge on the Battlefield,” *The Weapon Systems Technology Information Analysis Center Quarterly* 7, no 4: 4.

³FM 3-0.

⁴The Custodian, “RHA,” <http://everything2.com/title/RHA> (accessed December 17, 2009).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Disruptive technology as a phenomenon of markets and invention has been observed throughout the history of invention. However, disruptive technology has been on battlefields throughout history although it was not known as military disruptive technology. It has been known as military innovation and advanced technology for about the last 100 years. In the last 15 years, it has come to be known as disruptive technology. The classification of a technology as a military disruptive technology has been attacked by committees and individuals alike in the last 10 years in order to discern its strategic value to the United States. The term —disruptive technology” has been used to describe areas that are not necessarily disruptive technologies, but rather, new fronts on the modern battlefield, space and cyberspace. Disruptive technology has also been used to describe technology effects that are not necessarily disruptive but rather cause disruption in an adversary.

The term —disruptive technology” is poor when analyzing new technologies with military application. It is a commercial term and follows commercial market theories, whereas the creation, development, and implementation of military-oriented disruptive technologies fall into different rule sets. Therefore, the term —military disruptive technology” must be used to encompass not only the base of the commercial disruptive technology market theory but also the nature of strategic, operational and tactical advantage and importance in the application of that technology.

Military disruptive technology and civilian disruptive technology hold common characteristics but also have differences. Some characteristics common to both civilian and military disruptive technologies are:

1. Traditionally, leaders do not want to invest in future unknown technologies.
2. Investment is generally limited to what is known currently to improve design to make the technology better not necessarily create something new.
3. New disruptive technologies are evaluated with currently accepted metrics which may not be the right metrics for effectiveness.
4. Disruptive technology falls into two categories, one category is improvement due to a breakthrough in feeder technology causing a large change in entrenched technology and the second category is a completely new technology with new applications and markets.

Some characteristics of military disruptive technology which make it different from civilian disruptive technology are:

1. Exclusively financed and developed with intent to use in military offensive, defensive, or support operations.
2. May not have civilian application at onset.
3. Driven by operational needs and future possibilities.
4. Can be the cause of technological surprise which, if drastic enough, could cause mitigation of tactical and technical superiority.
5. It offers a strategic, operational, or tactical advantage for BLUE forces or mitigation of current strategic, operational, or tactical advantages of BLUE forces.

Military disruptive technology is currently identified with quantitative and qualitative methods by at least two white organizations working for the intelligence community. There are several defense-minded thinkers who have identified potential disruptive technologies using only one or two aspects of either of the two methods that the CDIATFR and the CFFDT use and are subjective and extrapolative in nature. Subjective and extrapolative prediction is predominant in these non-technical descriptions. These reports also give impact and the name of the technology. However unscientific those predictions are, they still belong in a pile of potential disruptive technologies because they have been imagined by someone. The dream of powered flight has been imagined for millennia, drawn by Leonardo Da Vinci in his notebooks in the 16th Century and written about in science fiction during the last two centuries, but only come into reality in the last century.

There are two problems stemming from the CDIATFR and CFFDT evaluations of disruptive technology. The first supposition is that the CDIATFR and CFFDT are overall concerned with national security. Because they examine several technologies and evaluation methodologies from a national security standpoint first, not necessarily from the military standpoint, they may miss some strategic, operational and tactical situations that may arise on the battlefield. The second problem in common with the Black Swan theory is that academics and businessmen with knowledge of technologies on the horizon could become subject to groupthink. Groupthink causes each group to conjecture as a whole and generally weeds out ideas that are outside accepted thinking but wholly possible, though unexpected. Again, subjective and predictive analysis of new disruptive

technologies without the military lens could cause possible technological surprise on the battlefield.

The development timeline of military disruptive technologies facing the United States in the next 20 years is an imperative. Though imperative, it draws on suppositions and awkwardly enough, again on the Black Swan Theory based on what is known and predominantly what is not known. While many of the thinkers have stated the importance of intelligence in order to decrease what is not known, the value of outside-the-box thinkers, futurists, scientists are imperative to thinking of disruptive technologies and their impacts on the future. The first two stages of the proposed stages of a military disruptive technology model are the most important and are generally the longest in the development of a currently non-existent military disruptive technology. The ability for a military to adapt to a technological surprise is imperative in the third phase of implementation. Albeit, the military is transforming into a force which can handle many possibilities that may be unforeseen, the impact of an improbable disruptive technology achieved by an adversary can have devastating strategic, operational, and tactical effects. The ability for a military or nation to adapt to the implementation of a new disruptive technology is imperative in the next two stages of military disruptive technology development. If a nation languishes in the fourth or fifth phase of military disruptive technology adaptation or counter technology development, it will be dominated or perish.

Even as the United States enjoys a technological edge over the rest of the world, it is naïve to think that military disruptive technologies are being pursued by military competitors other than to gain a military advantage over the United States. The United States has developed at least two white committees to forecast future military disruptive

technologies facing the United States. These committees are using the latest in predictive software programs to determine areas of future military disruptive technologies. Even with these two committees, leaders in the United States military must take an active role in learning generally about disruptive technologies and some specifics in their area of expertise. Senior leaders are the champions of potential military disruptive technologies being adopted by the military because they have the ability to influence application of funds by Congress into those areas. Junior officers, non commissioned officers and soldiers are the innovators on the battlefield and have direct hands on experience with many of the new technologies that are procured by the military. They are also more prone to be familiar with new “fringe” commercial technologies which may have application when merged with known military technologies.

Throughout all literature on military innovation, disruptive challenges, disruptive technology, and the CDIATFR and CFFDT reports, a good intelligence system is emphasized. The globalization of the world by the internet enables information to be shared, modified, expounded upon, and developed by everyone from the layman to the scientist and therefore increases the likelihood of a new military disruptive technology achievement. However, this globalization of information also works to the United States benefit because of the intelligence community’s ability to find the information and analyze it. Intelligence is a vital ingredient to preventing technological surprise on the battlefield. The implementation of a new, unforeseen military disruptive technology against BLUE forces that it does not have the versatility to overcome could be devastating to the United States. While the intelligence community is looking at

disruptive technology, the military must also develop a methodology to evaluate new potential disruptive technologies from their perspective.

Recommendations

Military disruptive technology must be distinguished from the noise that has developed in the last 10 years labeling the glut of new technologies as “disruptive.” Labeling space, cyberspace, and asymmetric warfare as “disruptive technology” or “disruptive in nature” and thus causing connotation that they are disruptive technologies is simply poor nomenclature. Space and cyberspace are dimensions of the full spectrum operations battlefield in which military disruptive technology will arise in the next 20 years. Asymmetric warfare will almost certainly cause more military innovations as adversaries attempt to use available technology in new ways to undermine the United States technological superiority. This is not to say that they will not seize any opportunity to find, steal, or develop a new unknown military disruptive technology that provides them advantage.

Although there are two white committees to evaluate potential disruptive technologies and predictive possibilities, it seems that they violate some of the principles of recognizing potential military disruptive technologies. Taleb’s Black Swan theory is important in that conventional wisdom and groupthink may cloud the ability to predict possibilities when two or three technologies combine into a new disruptive technology. Conventional wisdom and groupthink are both warned against in the CDIATFR and CFFDT reports as well. It seems that most, if not all of the committees are think tank members and not necessarily military members. All seem to be tenured professors, undoubtedly experts in their fields and most likely well-versed in the current state of their

fields. However, as the members collaborate they most likely fall into group think safe in their knowledge of what they know.

A proposal for change or adaptation would be to bring a combination of younger academic and technologically-inclined minds for live brainstorming of potential technology combination development. Unfortunately, this is not enough because academic- and technologically-inclined individuals familiar with the science behind new technologies do not have the military understanding, perspective, and implications of new military disruptive technologies. In addition, perhaps a simple survey of young soldiers and officers of technological possibilities and their effects that they see on the battlefield in the next 20 years. The United States Department of Defense should conduct its own analysis of potential military disruptive technologies in conjunction with its reliance on the intelligence communities forecasts.

The building block technologies that will fuel the most probability of new military disruptive technologies are:

1. Robotics.
2. Fuel cell and distributed energy technology.
3. Materials development.
4. Nano- and bio-technology advances.
5. Sports medicine advances.

These technologies will most likely have the predominance of advances that when combined with other existing technologies or technologies in development will become disruptive technologies. All these building block technology areas will support development in multiple military disruptive technology areas. These areas will be

evaluated with metrics that we currently use for acquisition, but the history of commercial and military disruptive technologies dictate that the performance metrics cannot be too firm lest their value be minimized and overlooked.

From the above building block technology areas, the top five disruptive technology areas currently foreseen in the next 20 years are:

1. Robotics as a weapon system.
2. Powered combat or battle armor as a weapon system.
3. Nano-technology and bio-technology as an offensive or defensive weapon system.
4. Lasers as a weapon system.
5. Communications as a support system.

These technologies follow the same guidelines as the “building block” technologies as their performance metrics must be soft to allow continued improvement in technology. As commercial disruptive technology studies have shown, generally the performance of the initial disruptive technologies is lower than current entrenched technologies but because they provided a new capability, they were able to usurp market leaders and replace entrenched technologies. Using hard performance metrics which have governed acquisition for the previous 25 years could cause an adversary to field these systems before the United States or even before the United States has developed counters for them.

Based on the literature encountered during the research, it seems that there is a firm foundation of interest in future military disruptive technologies by academia and intelligence circles. However, the indication by the literature is that the number of

military members whom could be the champions of future disruptive technologies funding today is very low. This is due to the fact that most military leaders are attempting to improve in the traditional, irregular, and catastrophic challenges facing the military in the next 20 years. While the military layman is focusing in these areas and attempting to transform the military to a more versatile structure, there are several potential military disruptive technologies effectiveness with catastrophic effects are that versatility cannot insulate against.

The use of the term disruptive technology used at military and intelligence disruptive technology conferences is incorrectly applied to areas where disruptive technology could occur rather than disruptive technologies themselves. The term disruptive technology has also been misapplied to disruption technology. Disruption is not the same as disruptive, however, the term disruptive technology is misapplied to disruption technology. Again, some potential new disruption technologies may be potential disruptive technologies not all of them should be portrayed as disruptive technologies.

Military disruptive technology is clearly different from commercial disruptive technology. The intelligence community seems to be quite aware of potential disruptive technologies in the next 20 years but, as it became apparent during research, only a smattering of potential military disruptive technologies are being introduced as possibilities to the United States military. This approach is clearly flawed and does little to prevent inherent technological surprise on the battlefield if the military is not aware of these possibilities and can at least contemplate them, let alone train for them or develop counters. The United States military is in constant transformation and has been developed

to be a versatile combat force, however, if potential military disruptive technologies are not contemplated, identified, developed, and implemented, it may find itself like the defeated French at Agincourt.

GLOSSARY

Artificial Intelligence. The study and design of intelligent agents.

Asymmetrical Warfare. A military situation where two groups of unequal power interact and attempt to exploit each other's characteristic weaknesses.

Black Swan. A highly improbable event with three principle characteristics: It is unpredictable; it carries a massive impact; and after the fact, we concoct an explanation that makes it appear less random, and even more predictable, than it was.

Building Block Technology. Advanced information technology, biotechnology, microtechnology, and nanotechnology that provides the foundation for militarily relevant capabilities.

Catastrophic Security Challenge. Challenge from adversaries seeking to paralyze American leadership and power by employing WMD or WMD-like effects in surprise attacks on critical, symbolic, or other high-value targets.

Cybernetics. The study of control and communication in the animal and machine.

Displaced (Marginalized) Technology. A technology or innovation that, when disruptive technology is introduced, quickly becomes obsolete.

Evolutionary Technology. An innovation that improves a product in an existing market in ways that customers are expecting. (E.g., fuel injection or hydrogen fuel cells).

Irregular Security Challenge. Challenge from those seeking to erode American influence and power by employing unconventional or irregular methods.

Marginalized (Displaced) Technology. A technology or innovation that, when disruptive technology is introduced, become quickly obsolete.

Revolutionary Technology. An innovation that creates a new market by allowing customers to solve a problem in a radically new way. (E.g., the automobile).

Singularity . An explosive advance in technology that unexpectedly leaves humans behind.

Traditional Security Challenge. Challenge posed by states employing recognized military capabilities and forces in well understood forms of military competition and conflict.

APPENDIX A

Daneels Themes and Questions for Disruptive Technology Research

Table I. Themes and Questions for Disruptive Technology Research

<p>Definition of Disruptive Technology</p> <ul style="list-style-type: none"> • Are there different types of technological change? What would be the dimensions of a typology? • Is disruptive technology a distinct type of technological change, and if so, how is it different? • Is a technology inherently disruptive, or does disruptiveness depend on the perspective of the firms confronted with the technological change? • At what point can disruption be said to have occurred? • Do different types of technological change have different sorts of impact on firms and industries? • What are the mechanisms by which technological change impacts firms and industries? • Does the impact of technological disruption depend on the structure (i.e., size, heterogeneity, evolution) of the market segments? <p>Predictive Use of the Theory of Technological Disruption</p> <ul style="list-style-type: none"> • Can a theory of the impact of technological change be used to make ex ante predictions about the fates of particular firms and industries? • Do these predictions generalize across different industries? • Can these predictions form the basis for managerial prescriptions? • How can a potentially disruptive technology be spotted in its early stage? • Can predictions be made regarding the origin and likely success of entrants? <p>Explaining the Success of Incumbents</p> <ul style="list-style-type: none"> • What are characteristics of incumbents that survive and prosper in the face of disruptive technological change in comparison with those that falter? • What innovation processes (e.g., resource allocation, culture, decision-making) characterize successful versus faltering incumbents? • How does the legacy (e.g., in assets, operating procedures, relational embeddedness) of incumbent firms affect their ability to harness technological change? • Where do entrants come from? What is the basis of their success? • How do modes of resource acquisition (such as alliances, joint ventures, acquisitions, and licensing) affect the fates of entrants and incumbents? • What is the impact of a marketing capability on the fate of incumbents when faced with a disruptive technology? • What is the role of the competence of individual middle- or top-level managers of incumbent firms? • What aspects of national context affect the success of incumbents relative to entrants? <p>The Merits of Being Customer-Oriented under Disruptive Technological Change</p> <ul style="list-style-type: none"> • Is a customer-oriented firm less apt to survive a technological change? • Does the focus of customer orientation to current versus potential customers impact the fate of incumbents? • How does the relationship with current customers drive investments in technological alternatives? • Which customer research tools inhibit versus facilitate successful harnessing of technological disruption? <p>The Merits of Creating a Spin-Off to Pursue Disruptive Technology</p> <ul style="list-style-type: none"> • What are the advantages and disadvantages of creating a separate organization to pursue disruptive technology? • Are these advantages and disadvantages different for the technological and commercial stages of this pursuit? • What should be the nature of the separation between the spin-off and the mainstream organization, in terms of resource allocation, decision-processes, culture, and so forth? • How should the relationship between the mainstream organization and the spin-off be structured (e.g., in terms of resources, governance, ownership, incentives) to minimize the interference and maximize the synergies between the spin-off and the mainstream organizations? • Under what conditions is a spin-off the best way to pursue disruptive technology?

Figure 8. Themes and Questions for Disruptive Technology Research

Source: Erwin Daneels, "Disruptive Technology Reconsidered: A Critique and Research Agenda," *Journal of Product Innovation Management* 248.

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